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Concussion and head injuries in English community rugby union match play

Authors:

Simon P. Roberts, PhD, Department for Health, University of Bath, Bath, UK

Grant Trewartha, PhD, Department for Health, University of Bath, Bath, UK

Mike England, MBBS, Rugby Football Union, Twickenham, UK

William Goodison, MD, Royal National Orthopaedic Hospital, UK

Keith A. Stokes, PhD, Department for Health, University of Bath, Bath, UK

Corresponding Author:

Name: Simon P Roberts

Postal: Department for Health, University of Bath, Bath BA2 7AY

Email: s.p.roberts@bath.ac.uk

Phone: +44(0)1225 384531

Fax: +44(0)1225 383833

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ABSTRACT

Background: Previous research has described general injury patterns in community level rugby union but specific information on time-loss head injuries has not been reported.

Objectives To establish the incidence and nature of significant time-loss head injuries in English community rugby match play, and to identify the injury risk for specific contact events.

Study design: Descriptive epidemiology study.

Methods Over six seasons, injury information was collected from 46 (2009/10), 67 (2010/11), 76 (2011/12), 50 (2012/13), 67 (2013/14) and 58 (2014/15) English community rugby clubs (RFU levels 3-9), over a total of 175,940 hours of player match exposure. Club injury management staff reported information for all head injuries sustained during match play whereby the player was absent for 8 days or greater. Clubs were subdivided into semi-professional (mean player age: 24.6 ± 4.7 years), amateur (24.9 ± 5.1 years) and recreational (25.6 ± 6.1 years) playing levels. Contact events from a sample of 30 matches filmed over seasons 2009/10, 2010/11 and 2011/12, provided mean values for frequency of contact events.

Results: The overall incidence for time-loss head injuries was 2.43 injuries per 1000 player match hours with a higher incidence for amateur (2.78; 95% CI 2.37-3.20) compared with recreational (2.20; 95% CI 1.86-2.53; P = 0.032) but not different to semi-professional (2.31; 95% CI 1.83-2.79) playing levels. Concussion was the most common time-loss head injury with 1.46 per 1000 player match hours. The tackle event was associated with 64% of all head

injuries and 73% of all concussions. There was also a higher risk of injury per tackle (0.33 per 1000 events; 95% CI 0.30-0.37) compared with all other contact events.

Conclusions: Concussion was the most common head injury diagnosis, although it is likely that this injury was under-reported. Continuing education programmes for medical staff and players are essential for the improved identification and management of these injuries. With the majority of head injuries occurring in the tackle, improved technique in this contact event through coach and player education may be effective in reducing these injuries.

What is known about this subject

The limited number of existing injury epidemiology studies in community rugby union have provided information showing that head injuries account a significant proportion of the overall injury load. Concussions in particular account for a considerable proportion of head injuries. However, specific information relating to injured player position, injury causing event and differentiation between playing levels for head injuries sustained during match play is limited. In addition no studies have investigated the risk of injury for a given contact event.

What this study adds to existing knowledge

This study describes the frequency and nature of head injuries at different levels of English community rugby union match play over multiple seasons and with a large study cohort. Specific information on the severity, injury event and diagnosis has also been reported in this population for the first time.

Assessing the number of contact events per match has allowed the calculation of head injury risk per contact event.

CONCUSSION AND HEAD INJURIES IN ENGLISH COMMUNITY RUGBY UNION MATCH PLAY

INTRODUCTION

Head injuries are of particular interest in all sports because of the potential for concussion and even severe traumatic brain injury. Rugby union is a contact sport comprising bouts of physical collision, interspersed with intermittent high-intensity running activity [28]. The majority of injuries in rugby are sustained in contact events [25, 29], many of which include the potential for impacts to the head.

There is general agreement in the available literature that head injuries contribute to a considerable proportion of the overall injury rate, with approximately 16% of all time-loss injuries in the elite game [30]. In community rugby, head injuries account for 24% of all medical attendance injuries [27] and 12 [25] to 16% [18] of all time-loss injuries (one week or greater absence from match play). Of all head injuries, concussion is the most commonly reported diagnosis [4, 18]. While there are numerous studies which provide information on head injuries and concussion in the elite men's game [1, 2, 4, 5, 7, 14], there is only limited information available in community rugby union. In a recent meta-analysis of concussion in rugby union, only three studies from below the elite level considered to report incidence according to appropriate methodological standards were included to return a mean of 2.08 concussions per 1000 player match hours [11]. Although some community level studies have reported the overall incidence of head injuries with limited information for injury diagnosis, there is no literature available which presents more detailed information such

as the severity and the match events specifically associated with head injuries at this level of rugby. It should also be considered that there is a considerable range of playing standards within men's community rugby and therefore differentiation between these levels is warranted.

Previous studies have investigated the propensity for specific contact events to cause injury in both elite [9] and community level rugby [26]. These studies demonstrated that illegal tackles returned the highest injury risk per event but also that (legal) tackles accounted for the greatest loss of match time [9, 26]. However, information was only reported for all injury diagnoses combined and therefore the community match play contact event with the greatest risk for head injury is yet to be determined.

The primary aim of this study was to investigate the incidence, nature and severity of time-loss head injuries in community rugby union match play, with particular reference to concussion. A secondary aim was to determine the risk of head injury for specific match events.

METHODS

Participants

Senior male first team squads at English community-level clubs participating in the Rugby Football Union (RFU) league structure within playing levels 3-9 were invited to participate in the study. Player demographics for the playing population are presented in Table 1. Data were collected over six seasons [2009/10, n=46 clubs (61 clubs at start of season); 2010/11, n=67 (90 clubs at start of season); 2011/12, n=76 clubs (104 clubs at start of season); 2012/13, n=50 club (106 clubs at the start of the season); 2013/14, n=67 (120 clubs at the start of the season); 2014/15, n=58 (102 clubs at the start of the season)]. Each season, some clubs dropped out from the study if staff left the club or decided to discontinue with data collection during the season. All matches were played over the normal English rugby union season, lasting between September and the following April. To facilitate comparisons across playing levels, clubs were classified as 'Semi-professional' at RFU levels 3 and 4, the highest level of English community rugby; 'Amateur' at RFU levels 5 and 6; and 'Recreational' at RFU levels 7, 8 and 9. It is accepted that these definitions are approximate and there will be varied practice/approaches across clubs. Having been provided with information about the study, individual players could opt-out from participation by informing club medical staff who omitted information on that player. Injury management staff did not provide any details of players who opted out. The study had institutional ethics approval.

INSERT TABLE 1 NEAR HERE

155

156 **Injury reporting**

157 Injury management staff (holding an accredited sports therapist qualification as
158 a minimum) at participating clubs completed and returned injury forms. Any
159 head injury incurred during a first team match resulting in an absence from
160 participation in match play for one week or more from the day of the injury was
161 defined as a “time-loss” head injury. This time-loss definition was used because
162 in most community level teams, the players have infrequent contact with their
163 injury management staff which may compromise the reporting of injuries of less
164 than one week. For the purposes of the current study, concussions were
165 reported by the club injury manager based on their own understanding and
166 diagnosis of a concussion. The date of the first match following the injury on
167 which the player was fit enough to be available for selection (whether or not he
168 actually played) was recorded as the return to play date, and injury severity was
169 defined by the number of weeks missed. Therefore, the least severe injuries
170 are ‘moderate’ (8-28 days absence) according to the consensus statement for
171 injury definitions and data collection procedures for studies of injuries in rugby
172 [10]. Guidelines for the return to play protocols following concussion, throughout
173 the data collection period, are included in Table 2.

174

175 INSERT TABLE 2 NEAR HERE

176

177 For all time-loss injuries, information was recorded on the type, injury event,
178 treatment, time of injury and severity (number of weeks missed through injury)
179 using a standard report form. Details on the type of injury were recorded using

the Orchard Sports Injury Classification System version 8 [23] by the injury management personnel in discussion with the player with regard to the inciting event. For 0.5% of all injuries, the inciting event was unknown. Only head injuries incurred during match play at the participating clubs were recorded and therefore absences from match play due to injuries incurred through any other activity (including rugby training) were not included.

Match Analysis

Footage from 30 community rugby matches (10 matches from each group) filmed over seasons 2009/10, 2010/11 and 2011/12, was analysed to determine mean values for the number of contact events occurring within match play at the playing levels described for this study. This match footage was obtained from the same playing levels as those from which the injuries were reported but the specific matches were not related. This analysis was made with the purpose of combining the number of injuries and values for the mean number of contact events per match to determine values for the risk of injury per contact event.

Matches were filmed from an elevated position using one video camera (Sony DCR-TRV900E, Japan) mounted on a tripod. The ball was kept in the centre of the view with an approximate radius of 10 m. Match footage was captured to analysis software (SportsCode Pro 7.0.150, Sportstec, Australia). Every contact event (tackle: tackler stops the progress of the ball carrier with the use of his arms; (illegal) collision tackle: tackler stops the progress of the ball carrier without the use of his arms; ruck: one or more players from each team

contesting with the ball on the ground; maul: ball carrier in contact with at least two other players on their feet; lineout: a minimum of two players from each team contesting a ball thrown in by one team to re-start play and scrum: eight players from each team pushing against each other in a crouched position and contesting the ball fed in by one team to re-start play) was identified and recorded.

Data Analysis

Playing positions were grouped as forwards and backs, then subdivided into front row (props and hooker), second row, back row (flankers and No. 8), scrum halves, inside backs (fly half and centres) and outside backs (wingers and full backs). Data were combined for all seasons. Injury incidence was recorded as the number of injuries per 1000 player hours of match exposure. Player hours of match exposure was calculated by the number of matches x number of players per team x match duration (hours).

For the propensity (risk per event) calculations, the total number of match play contact events (over the 8797 matches from which the injury data was reported) was estimated by multiplying the mean number over the 30 recorded matches by the number of matches (8797). In addition, the number of injuries was multiplied by 1.93 to account for the fact that two teams were always exposed to the risk of injury from the contact events (which would have resulted in a multiplication factor of 2), but on a small number of occasions two participating teams within this study played each other and therefore the injuries for both teams would be reported [26]. Propensity of a contact event to cause a head

injury was therefore expressed as the number of injuries for each type of contact per 1000 events.

Differences between groups were determined using a two-tailed Z test for comparison of rates. Differences were deemed to be statistically significant if $P \leq 0.05$, and 95% confidence intervals (CI) were recorded for calculated variables. Player demographic data was non-normally distributed with unequal group sizes and therefore differences between groups were determined using the Kruskall-Wallis-test with post-hoc analysis using the Mann-Whitney test.

RESULTS

Overall incidence and severity

In total, 8797 team games were included in this study, with a mean of 24 games per club per season. Overall, there was a total of 427 head injuries over 175,940 hours of player match exposure. For Semi-professional, Amateur and Recreational playing levels, there were 38,120 (1906 matches), 62,200 (3110 matches) and 75,620 (3781 matches) player match hours resulting in 88, 173 and 166 injuries, respectively. The overall incidence of time-loss head injuries was 2.43 injuries per 1000 player match hours and was higher for Amateur (2.78; 95% CI 2.37-3.20) compared with Recreational (2.20; 95% CI 1.86-2.53; P = 0.032) playing levels and neither were different to Semi-professional (2.31; 95% CI 1.83-2.79) playing levels. (Table 3). There were 256 reported concussions with an overall incidence of 1.46 injuries per 1000 player match hours with no difference between playing levels (Table 3). The mean number of weeks missed per head injury for all playing levels combined was 4.8 (95% CI 4.3 to 5.2) (median of 3) for all head injuries, and 3.6 (95% CI 3.2 to 4.0) (median of 3) weeks for concussions. There was no difference between playing levels for the number of weeks missed due to all head injuries or concussions. Of all reported concussion injuries, 24% returned after two weeks, 35% returned after three weeks and 35% of cases missed more than 3 weeks. No return to play date was reported for 6% of all concussions. There was one head injury in every 21 team games, or every 10 matches involving two teams. There was one concussion in every 34 team games or one in every 17 matches. There was a higher incidence in season 2014/15 compared with all other seasons for both all head injuries and concussions (all $P < 0.05$) and in 2013/14 compared

with 2011/12 for all head injuries (P = 0.038) and compared with 2010/11 for concussions (P = 0.023) (Table 4).

TABLE 3 NEAR HERE

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Injury diagnoses

Concussion was the most commonly reported time-loss head injury, accounting for 60% of all head injuries, followed by fractures (15%) and then lacerations/abrasions (12%) (Table 5). The most severe injuries (i.e. those resulting in the highest mean number of weeks missed) were fractures. When combining the incidence of injuries and weeks missed (injury burden), 5.2 and 3.5 weeks per 1000 player match hours were missed for concussion and fractures, respectively. For 88% of all time-loss head injuries, the player was removed from play at the time of the injury, while players diagnosed with concussion were removed at the time of injury for 90% of injuries. Four percent of all concussions were reported as recurrences of previous concussion injuries although the time delay between the injuries was not available for analysis.

TABLE 5 NEAR HERE

Injury event

All head injuries were attributed to contact events. In total, 64% were sustained in the tackle (1.56 injuries per 1000 player match hours; 95% CI 1.38-1.75),

289 including both being tackled (0.60, 95% CI 0.49 to 0.72) and tackling another
290 player (0.78, 95% CI 0.65 to 0.91), along with illegal collision tackles (0.18, 95%
291 CI 0.12 to 0.24). Foul play, including punching, head butting and eye gouging,
292 was associated with 11% of head injuries. Most concussions were associated
293 with, tackling (38%) and being tackled (36%) (both legal and illegal collision
294 tackles).

295

296 **Player position**

297 There was no difference between forwards and backs in the incidence of either
298 all head injuries (forwards: 2.63, 95% CI 2.30 to 2.96; backs 2.19, 95% CI 1.87
299 to 2.51) or concussions (forwards: 1.48, 95% CI 1.24 to 1.73; backs 1.42, 95%
300 CI 1.17 to 1.68). For specific positional groups, back row forwards (3.47, 95%
301 CI 2.85 to 4.08) incurred a higher incidence of any head injury compared with
302 front rows (2.19, 95% CI 1.70 to 2.86; P = 0.002), second rows (2.05, 95% CI
303 1.47 to 2.63; P = 0.002), inside backs (2.07, 95% CI 1.60 to 2.55; P < 0.001)
304 and outside backs (2.27, 95% CI 1.78 to 2.77; P = 0.001). Back row forwards
305 (2.05, 95% CI 1.57 to 2.52) also incurred significantly more concussions
306 compared with front row forwards (1.14, 95% CI 0.78 to 1.49; P = 0.003),
307 second row forwards (1.15, 95% CI 0.72 to 1.59; P = 0.003) and inside backs
308 (1.22, 95% CI 0.86 to 1.59; P = 0.008).

309

310 **Timing of injuries**

311 There were significantly fewer head injuries in the 1st and 3rd match quarters,
312 compared with the 2nd and 4th quarters (Table 6). There were also fewer
313 concussions in the 1st match quarter compared with the 2nd and 4th quarters.

There was no difference in the severity of injuries between different match quarters. There was no difference in the incidence of concussions over the course of the season.

TABLE 6 NEAR HERE

Risk of injury by match contact event

There was an overall injury risk of 0.25 injuries per 1000 contact events and a significantly greater risk in Amateur matches (0.29 injuries per 1000 events; 95% CI 0.26 to 0.32) compared with Semi-professional (0.22 injuries per 1000 events; 95% CI 0.19 to 0.26; P = 0.008) but no difference compared with Recreational (0.25 injuries per 1000 events 95% CI 0.22 to 0.28). The overall risk of concussion per contact event was 0.15 concussions per 1000 contact events, with no difference between the different playing levels.

For all groups combined, the propensity for a contact event to result in injury was greatest for collision tackles (Table 7) at 4.90 head injuries per 1000 collisions tackles with the risk being highest for the tackled player in the collision. There was a significantly greater risk of injury per legal tackle compared with all other contact events (apart from collision tackles) but the risk was not different for the tackled or tackling player (Table 7).

TABLE 7 NEAR HERE

DISCUSSION

We investigated the incidence, severity and nature of time-loss head injuries in community-level rugby with a specific focus on concussion injuries. The incidence of match-related time-loss head injuries of 8 days or greater absence was found to be 2.43 per 1000 player match hours (12% of all injuries), with a mean severity of 4.8 weeks absence. Reported concussions accounted for 60% (1.46 per 1000 player match hours) of all time-loss head injuries with a mean of 3.6 weeks absence. Most head injuries were incurred in the tackle, with the illegal collision tackle in particular, being the highest risk contact event in terms of injuries per event.

The overall incidence of 2.43 head injuries per 1000 player match hours in the current study is comparable with that of 1.7 per 1000 players hours in Australian amateur grade rugby [20] but lower than previous studies reporting head injuries in professional [16] and international rugby [30]. This finding supports the largely accepted view that in rugby union, overall injury rates are higher for higher playing levels [3, 22, 25]; a pattern which was also identified previously between playing levels in English community rugby for both overall time-loss [25] and match play medical attention injuries [27]. While these different injury patterns have been attributed to a greater frequency [9, 26] and intensity of contact events in higher-level rugby [3], in the current study there was a higher incidence of time-loss head injuries in Amateur compared with Semi-professional playing levels despite there being fewer contact events during the match. This finding may be due in part to players at a higher level having greater technical proficiency in

362 the tackle, better physical conditioning, and possibly better access to medical
363 support to facilitate an earlier return to play.

364

365 The most common head injury diagnosis in the current study was concussion,
366 accounting for 60% of all head injuries and an incidence of 1.46 per 1000 player
367 match hours. This incidence is slightly lower compared with other community
368 rugby studies with equivalent concussion time-loss injury definitions of 2.2 [29]
369 and 1.7 [18] but higher than another study for male senior players reporting 0.8
370 per 1000 player match hours [20]. In a study of Australian non-professional
371 players, concussion (defined as mild Traumatic Brain Injury) was shown to be
372 7.97 per 1000 player game hours when the definition included non time-loss
373 injuries [12]. The variation in concussion incidence in studies of community rugby
374 can be attributed to a number of factors including the diverse levels of play,
375 variations in the medical support provided to players between studies and the
376 concussion definition [11].

377

378 It is likely that the concussion incidence in the current study is a minimum
379 estimate with the possibility that these injuries are under-reported in community
380 rugby union through lack of player awareness and/or unwillingness of players
381 to report symptoms to club staff. Evidence for this includes a study of 172
382 players who were asked to retrospectively self-report sustained concussions
383 over a season, with 45% reporting at least one concussion [6]. However, only
384 47% of these concussions were reported to club medical staff, suggesting that
385 data collected in prospective studies that rely on data capture by medical staff

386 are prone to under-reporting of this specific injury. A previous study has shown
387 that compliance with return to play regulations was low in community rugby
388 union players [13] and therefore it cannot be discounted that for some players,
389 the concussion may have been recognised but that the player returned to play
390 in the next match. We have shown previously that the incidence of match play
391 medical attendances for head laceration, contusion and neural injuries
392 combined was 45 attendances per 1000 player hours [27]. This finding is
393 noteworthy in the current context because it demonstrates a large discrepancy
394 between the incidence of seemingly minor (usually non time-loss) injures and
395 those injuries captured in the current study (eight days or greater absence),
396 thus highlighting the fact that pitch side medical staff should be vigilant to the
397 signs of concussion. It should also be considered that in some cases, the
398 outward signs of injuries such as lacerations or fractures may conceal the less
399 obvious signs of neurological disturbance related to concussion.
400
401 Incidence of reported concussion in professional rugby has increased in recent
402 seasons (5.1 per 1000 match hours in 2011/12 to 10.7 per 1000 match hours
403 in 2013/14) [17], and this has been largely attributed to increased awareness of
404 issues surrounding concussion [5]. Concussion incidence in the most recent
405 season of the current study was significantly higher than all earlier seasons and
406 coincides with recent media interest and increased educational activity through
407 the RFU 'Headcase' programme, which was launched in January 2013 to
408 promote concussion education and resources across all levels of the English
409 game [24]. Given the raised level of awareness, this finding is most likely to be
410 due to better understanding and diagnosis by both players and medical staff,

411 for example, the player not having to lose consciousness to be diagnosed.
412 While it is possible that a change in the physical demands of the game may
413 also be responsible for an increased concussion risk, this explanation is more
414 difficult to assess given that there is no evidence to support a change in the
415 match demands at this level of rugby over one season. Ongoing work will be
416 required to identify whether incidence of reported concussion continues to
417 increase in future seasons and should try to determine whether this is due to
418 greater awareness or changes in the risk associated with playing the game.

419

420 The overall mean of 3.6 weeks missed and 3 weeks or more absence for 70%
421 of concussions in the current study relates closely to the recommended stand
422 down time of three weeks mandated by the International Rugby Board (the
423 international federation for rugby, now World Rugby) until 2010. Another 24%
424 of all concussed players returned after two weeks (14 days) which is feasible
425 within the regulations in force for much of the current study period which
426 permitted the player to return at any point if they were symptom free and had
427 followed the graduated return to play protocol [19]. However guidelines
428 introduced in March 2014 [24] state that the earliest that an adult player can return
429 to play is 19 days following the concussion unless the player has access to an
430 enhanced care setting which is normally only available to professional players.
431 Therefore, it would be expected that in future seasons, the proportion of
432 community level players returning to play in less than 19 days will be small.
433 Ongoing work will assess whether concussion education programmes such as
434 the 'Recognise and remove' campaign promoted through RFU Headcase [24] and

435 World Rugby Player Welfare [15] influence both the incidence and the duration of
436 player absences for concussion in future seasons.

437

438 The tackle was the primary contact event associated with head injuries and
439 specifically concussions, which is a common finding in the literature [3, 18]. This
440 is not surprising given that this is also the most common contact event during
441 match play [26], but our analysis also shows that the risk of injury per tackle
442 (injuries per 1000 events) was higher than any other contact event. It is beyond
443 the scope of the current study to identify which specific aspects of the tackle
444 result in head injury but a previous study showed that head/neck injuries in elite
445 level players were most likely when this was the principal site of contact in the
446 tackle [8] and particularly when the tackler's head contacted the ball carrier's
447 lower leg [21]. These findings suggest that players adopting the appropriate head
448 position in the tackle (to the side, allowing shoulder to make contact) should be
449 an effective measure for reducing the risk of head injuries [21]. It is of note that
450 by far the greatest risk of head injury per event in the current study was
451 specifically for ball carriers in collision tackles, which are instances when the
452 tackling player stops the ball carrier without use of the arms. These tackles are
453 illegal, and our data highlight the need for strict officiating in relation to these
454 high risk events. Using a sample of 30 matches to estimate the number of
455 match events for all matches may potentially to introduce some bias. However
456 it would be expected that this sample provides an acceptable representation of
457 match events at this level of community rugby given that the confidence
458 intervals for all contact events were small for all groups combined and were

sufficient to show differences between playing levels (Supplementary Data: Table 9).

Conclusions

This study shows that concussions account for the majority of time-loss head injuries in English community rugby. Concussion regulations introduced at the end of the currently studied period state that the minimum stand down period for a player outside of the enhanced care setting is now 19 days and therefore future studies should demonstrate a substantial reduction from the 26% of players returning within this period in the current study. Given that the current incidence is likely to be a minimum estimate and the potential short, medium and long-term neurological implications for repeated concussion injuries, continued education for medical staff, coaches and players on the identification and management for head injuries, particularly concussion, is essential. With most head injuries associated with the tackle, good technique in this event may be effective in reducing these injuries.

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565 **TABLES**

566

567 Table 1. Player demographics (mean, range and number) for participants at different
568 playing levels. Values are derived from only seasons 2012/13 – 2014/15

569

Level	Age	Mass	Height
All Players	25.8 (17-55) (n=2916)	94.2 (56-154) (n=3629)	182.0 (150-213) (n=3676)
Semi-professional	24.7[ab] (17-41) (n=420)	96.7[bd] (69-145) (n=499)	183.4[be] (158-212) (n=495)
Amateur	25.6[c] (17-46) (n=1042)	95.1[b] (56-154) (n=1209)	181.8 (150-210) (n=1255)
Recreational	26.3 (17-55) (n=1454)	93.1 (56-150) (n=1921)	181.8 (150-213 (n=1926)

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571 [a]P = 0.007 *versus* Amateur; [b]P < 0.001 *versus* Recreational; [c]P = 0.025 *versus*
572 Recreational; [d]P = 0.005 *versus* Amateur; [e]P < 0.001 *versus* Amateur.

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Table 2. Return to play guidelines following a concussion throughout the study data collection period

Date	Guidelines
Until 2010	International Rugby Board* recommended a three-week stand down period
2010 to March 2014	International Rugby Board did not prescribe a stand down period and every case was judged on its own merits with GRTP (Graduated Return to Play) started once the player was symptom free. Therefore a player could have returned within 6 days.
March 2014 to present	Any player outside of the enhanced care setting (accounting for the vast majority of community level players) could not return to play in less than 19 days.

*Now World Rugby

585

586 Table 3. Number of injuries, incidence and severity of injuries for all groups
587 combined and for each playing group. *Incidence per 1000 player match hours
588 (95% CI).

		Total Number of Injuries	Incidence* (95% CI)	Severity (Weeks Missed) (95% CI)
Head Injuries				
	All Players	427	2.43 (2.20-2.66)	4.8 (4.3-5.3)
	Semi-professional	88	2.31 (1.83-2.79)	4.2 (3.4-5.2)
	Amateur	173	2.78 (2.37-3.20)[a]	5.2 (4.5-6.1)
	Recreational	166	2.20 (1.86-2.53)	4.6 (3.9-5.3)
Concussion				
	All Players	256	1.46 (1.28-1.63)	3.6 (3.2-4.0)
	Semi-professional	62	1.63 (1.22-2.03)	3.3 (2.6-4.3)
	Amateur	98	1.58 (1.26-1.89)	3.8 (3.1-4.6)
	Recreational	96	1.27 (1.02-1.52)	3.5 (2.9-4.3)

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590 [a]P = 0.032 *versus* Recreational
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Table 4. Number and incidence of all head injuries and concussions over the six seasons with all playing levels combined. Incidence per 1000 player match hours (95% CI).

		All head injuries		Concussion	
Season	Total match exposure	Number	Incidence (95% CI)	Number	Incidence (95% CI)
2009/10	22,540	44	1.95 (1.45-2.62)	25	1.11 (0.75-1.64)
2010/11	33,060	70	2.12 (1.68-2.68)	32	0.97 (0.68-1.37)[b]
2011/12	37,100	74	1.99 (1.59-2.51)[a]	51	1.37 (1.04-1.81)
2012/13	24,040	50	2.08 (1.58-2.74)	25	1.04 (0.70-1.54)
2013/14	32,180	89	2.77 (2.25-3.40)	52	1.62 (1.23-2.12)
2014/15	27,020	100	3.70 (2.98-4.43)[c]	71	2.63 (2.02-3.24)[c]

[a]P = 0.038 and [b]P = 0.023 *versus* 2013/14. [c]P < 0.05 *versus* all other seasons.

600 Table 5. The number of injuries, incidence and severity of different injury
601 diagnoses. *Incidence per 1000 player match hours (95% CI).

Diagnosis	Number (% of all head injuries)	Incidence* (95% CI)	Mean severity (weeks missed) (95% CI)
Concussion	256 (60)	1.46 (1.28-1.63)[a]	3.6 (3.2-4.0)
All fractures	62 (15)	0.35 (0.26-0.44)[bcde]	9.8 (7.6-12.6)
Nose fracture	*23 (5)*	*0.13 (0.08-0.18)*	*5.5 (3.6-8.2)*
Skull fracture	*2 (1)*	*0.01 (0.00-0.03)*	*8.0 (2.0-32.0)*
Mandible fracture	*9 (2)*	*0.05 (0.02-0.08)*	*16.5 (8.6-31.7)*
Maxilla,zygoma,orbit frac	*24 (6)*	*0.14 (0.08-0.19)*	*10.4 (7.0-15.5)*
Unspecified fracture	*4 (1)*	*0.02 (0.00-0.04)*	*19.1 (6.2-59.1)*
Lacerations/abrasions	53 (12)	0.30 (0.22-0.38)[bcde]	5.5 (4.2-7.2)
Bruising	18 (4)	0.10 (0.06-0.15)	3.7 (2.3-5.9)
Eye injury	16 (4)	0.09 (0.05-0.14)[de]	3.5 (2.1-5.7)
Jaw dislocation/sprain	5 (1)	0.03 (0.00-0.05)	3.5 (1.5-8.4)
Dental	7 (2)	0.04 (0.01-0.07)	8.8 (4.2-18.5)
Other head Injuries	10 (2)	0.06 (0.02-0.09)	2.7 (1.3-5.7)

602
603 [a]P < 0.001 *versus* all other diagnoses; [b]P < 0.001 *versus* bruising; [c]P < 0.001
604 *versus* eye injury; [d]P < 0.001 *versus* jaw dislocation/sprain; [e]P < 0.001 *versus*
605 dental.
606
607

608 Table 6. The number and severity of all time-loss head injuries combined and
609 concussion injuries associated with match quarter.

610

	All head injuries		Concussion	
Match quarter	Incidence (95% CI)	Severity (Weeks Missed) (95% CI)	Incidence (95% CI)	Severity (Weeks Missed) (95% CI)
0-20	1.68 (1.30-2.07)	5.9 (4.7-7.4)	1.05 (0.74-1.35)	3.8 (2.8-5.1)
21-40+	2.73 (2.24-3.22)[ab]	4.2 (3.6-5.1)	1.57 (1.20-1.94)[c]	3.3 (2.6-4.2)
41-60	2.07 (1.64-2.49)	4.5 (3.7-5.5)	1.23 (0.90-1.56)	3.5 (2.7-4.6)
61-80+	2.77 (2.28-3.27)[ab]	4.8 (4.0-5.7)	1.68 (1.30-2.07)[c]	3.8 (3.1-4.8)
Unknown	0.45 (-.26-0.65)	4.5 (2.9-6.9)	0.30 (0.13-0.46)	2.8 (1.7-4.9)

611 [a]$P < 0.001$ *versus* 0-20; [b]$P < 0.05$ *versus* 41-60; [c]$P < 0.05$ vs 0-20

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618 Table 7. Incidence of head injuries per 1000 contacts events for all groups
619 combined.

	Injuries per 1000 events (95% CI)	
	All Head injuries	Concussion
All match contact events	0.25 (0.24-0.27)	0.15 (0.14-0.17)
All tackles (legal & collision)	0.33 (0.30-0.37)	0.29 (0.26-0.32)
All tackles (legal)	0.29 (0.26-0.32)[bcde]	0.27 (0.24-0.30)[bcde]
Tackled (legal)	*0.17 (0.14-0.19)*[bcdef]	*0.12 (0.10-0.14)*[bcde]
Tackling (legal)	*0.21 (0.19-0.24)*[bcdef]	*0.15 (0.13-0.17)*[bcde]
All collision tackles	4.90 (3.82-6.29)[a]	2.45 (1.72-3.48)[a]
Collision tackled	*4.44 (3.42-5.77)*[bcde]	*2.14 (1.47-3.12)*[bcde]
Collison tackling	*0.46 (0.20-1.04)*[bcde]	*0.31 (0.11-0.83)*[bcde]
Ruck	0.09 (0.07-0.11)[defg]	0.05 (0.04-0.07)[defg]
Maul	0.08 (0.05-0.12)[defg]	0.02 (0.01-0.05)[efg]
Scrum	0.03 (0.01-0.06)[fg]	0.01 (0.00-0.03)[fg]
Lineout	0.01 (0.00-0.04)[fg]	0.00 (0.00-0.00)[fg]

620

621 [a]P < 0.001 *versus* all other events; [b]P < 0.001 *versus* ruck; [c]P < 0.001 *versus*
622 maul; [d]P < 0.001 *versus* scrum; [e]P < 0.001 *versus* lineout, [f]P < 0.001 *versus*
623 all types of collision tackles; [g]P < 0.001 *versus* all types of tackles

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627 **Supplementary Data**: Table 8. The number and severity of all time-loss head
628 injuries combined and concussion injuries associated with specific match
629 events.

Event	Number (% of all head/concussion injuries)	Incidence	Mean severity (Weeks missed) (95% CI)
All head injuries combined			
All tackles (legal & collision)	275 (64)	1.56 (1.38-1.75)	4.6 (4.1-5.2)
All Tackles (legal)	243 (57)	1.38 (1.21-1.55)	4.5 (4.0-5.1)
Tackled	*106 (25)*	*0.60 (0.49-0.72)[bcd]*	*4.5 (3.7-5.4)*
Tackling	*137 (32)*	*0.78 (0.65-0.91)[a]*	*4.6 (3.9-5.4)*
All collision tackles	32 (8)	0.18 (0.12-0.24)	5.4 (3.8-7.6)
Tackled collision	*29 (7)*	*0.16 (0.10-0.22)*	*4.8 (3.3-6.9)*
Tackling collision	*3 (1)*	*0.02 (0.00-0.04)*	*11.0 (3.5-34.1)*
Accidental Collision	29 (7)	0.16 (0.10-0.22)	3.1 (2.1-4.4)
Ruck/Maul	54 (13)	0.31 (0.23-0.39)	5.0 (3.8-6.6)
Punched	35 (8)	0.20 (0.13-0.26)	6.9 (5.0-9.6)
Concussion			
All tackles (legal & collision)	187 (73)	1.06 (0.91-1.22)	3.7 (3.2-4.2)
All Tackles (legal)	171 (67)	0.97 (0.83-1.12)	3.7 (3.2-4.3)
Tackled	*77 (30)*	*0.44 (0.34-0.54)[bcd]*	*3.9 (3.1-4.8)*
Tackling	*94 (37)*	*0.53 (0.43-0.64)[bcd]*	*3.6 (3.0-4.4)*
All collision tackles	16 (6)	0.09 (0.05-0.14)	2.9 (1.8-4.8)
Tackled collision	*14 (6)*	*0.08 (0.04-0.12)*	*2.9 (1.7-4.9)*
Tackling collision	*2 (1)*	*0.01 (0.00 – 0.03)*	*3.0 (0.8-12.0)*
Accidental Collision	14 (6)	0.08 (0.04-0.12)	3.5 (2.1-6.0)
Ruck/Maul	29 (11)	0.16 (0.10-0.22)	3.7 (2.6-5.4)
Punched	10 (4)	0.06 (0.02-0.09)	3.3 (1.8-6.1)

630
631 [a]P < 0.001 *versus* all other events; [b]P < 0.001 *versus* collision; [c]P < 0.001
632 *versus* ruck/maul; [d]P < 0.001 *versus* punched.

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634 **Supplementary data**: Table 9. Number of contacts events per match.

	Events per match (Mean ± 95% CI)
All Groups - All events	370.1 (363.8-377.6)
Group A - All events	*399.3 (387.1-411.9)[a]*
Group B - All events	*374.0 (362.2-386.2)[b]*
Group C - All events	*338.7 (327.5-350.3)*
All tackles (legal & collision)	142.3 (138.1-146.6)
All tackles (legal)	140.9 (136.7-145.2)
All collision tackles	1.4 (1.1-1.9)
Ruck	115.0 (111.2-118.9)
Maul	23.4 (21.7-25.2)
Scrum	32.2 (30.2-34.3)
Lineout	25.6 (23.9-27.5)

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636 [a]P < 0.05 *versus* Group B and Group C; [b]P < 0.001 *versus* Group C.

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